Northern Region Cone & Seed Insect Handbook

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Introduction

The purpose of this handbook is to provide seed orchard managers with a comprehensive reference that describes identification, life history, habits, and damage caused by cone and seed insects found in R1 seed orchards, or that are reported in the literature as major pests of seed orchard tree species grown in R1. Included are monitoring methods currently available (as of 2018) and management techniques used to reduce damage for each insect, including some that were attempted but were unsuccessful. Monitoring methods and management techniques will change as new procedures continue to be developed.

Cone and seed insects often cause severe cone crop losses in seed orchards, requiring management actions. These insect pest populations fluctuate in response to yearly variations in cone crops. Insect numbers build up as cone crops increase during mast years. When a low cone crop year follows a mast year, the large population of pests produced during the mast year can totally consume the small crop. However, insect numbers will drop considerably during low cone crop years due to poor reproduction in the scarce number of cones. Management treatments may then not be necessary the year following low or no cone crops, as insect populations may not have had time to recover (see Figure 41 in appendix). Some seed and cone insects have developed strategies such as diapause to survive low cone crop years. In diapause, insects remain in a suspended state for more than one year, increasing their chances of emerging during years with a more favorable cone crop.

An integrated pest management (IPM) approach that uses tactics such as monitoring cone crop variability, insect monitoring, sanitation, cone barriers, insecticide treatments as needed, and/or natural enemy enhancement may be the most economical and ecological strategy to reduce seed losses. General IPM options for seed orchards and a list of insecticides currently used by seed orchard managers are included in this handbook.

Insects Affecting Cones, Seeds, & Pollen on Conifer Species in Region 1 Seed Orchards

Cone & Seed Insect Pest	Pines	Douglas-fir	Western Larch	Monitoring Method
Cone beetle *Conophthorus ponderosae*	Major pest			Pheromone traps/ Visual
Western conifer seed bug *Leptoglossus occidentalis*	Major pest	Major pest	Occurs	Timed visual examination/ radiographs
Coneworms *Dioryctria abietivorella* and other species	Major pest	Major pest	Occurs	Pheromone traps/ Visual
Seedworms *Cydia piperana* complex	Major pest of ponderosa pine at some locations			Pheromone traps/ Visual
Western spruce budworm *Choristoneura freemani*		Major pest	Major pest	Visual/ Pheromone available
Douglas-fir cone moth *Barbara colfaxiana*		Major pest in literature		Pheromone traps using gall midge bait
Seed chalcids *Megastigmas* spp.	Occurs	Major pest in literature	Occurs	Yellow sticky traps/ radiographs
Douglas-fir cone gall midge *Contarinia oregonensis*		Major pest in literature on west coast		Pheromone traps/ Visual
Cone adelgids *Adelges* spp., *Pineus* spp.	Occurs	Occurs	Major pest affecting seed extraction	Visual
Cone maggot *Strobilomyia laricis*			Major pest in literature	Visual
Resin/Cone scale midges *Resseliella* spp.	Occurs	Occurs	Occurs	Visual
Xyelid sawflies on pollen catkins, *Xyella* spp.	Occurs			Visual

Note: This is not an all-inclusive list. It contains insects we have commonly seen or that have been listed as important in the literature for tree species in R1 seed orchards. Blank cells indicate the insect doesn't occur in that tree species. *Updated 2018*

General Integrated Pest Management Options for Seed Orchards

1. *Monitor*

   Use available monitoring methods. Some pests in R1 have pheromone traps available for monitoring. Others should be monitored by regular visual exams of cones throughout the growing season to detect insect signs externally or in bisected cones.

2. *Population Manipulation with Pheromones*

   For isolated seed orchards, mass trapping, mating disruption, or repellant techniques could have potential for managing insects with identified pheromones. In orchards bordered by host type, these techniques would be less effective because of pest immigration from surrounding areas.

3. *Sanitize Cones*

   Many insects overwinter inside cones. Certain species can remain there for two or more years in diapause and emerge in future years. Cones should be removed from orchards or burned before temperatures warm in the spring.

4. *Under-burning*

   For fire resistant trees, under-burning is effective in killing insects overwintering in cones on the ground. In the North Central States, a specially designed propane burner pulled behind a tractor has been used to kill cone beetles in eastern white pine cones fallen on the ground.

5. *Individual Cone Barriers*

   Fine mesh bags secured around cones can protect them from insects. This technique would be most practical on individual trees or families with particularly high value seed.

6. *Use Insecticides when Necessary*

   Several insecticides are registered for use in seed orchards to reduce insect damage to cones and seeds. Application timing is critical and must coincide with insect activity outside of cones unless using a systemic insecticide. Systemic insecticides need to be applied while there is sufficient time to be translocated to cones when insects are feeding.

7. *Flower Garden to Supplement Natural Enemies*

   Consider planting a variety of flowers in insecticide-free locations to provide supplemental food for natural parasites and predators to boost their populations. This practice has reduced pest populations in fruit orchards and vegetable crops.

Current Insecticides Used in Region 1 Seed Orchards for Managing Cone & Seed Insects

Insecticide	**Target Insect**	**No. of Applications**	**Month Applied** (varies by seed orchard)
Permethrin (Astro®, Tenkoz®)	cone beetles	Two	March/April/May/June
	western conifer seed bugs	Multiple (alternate with carbaryl)	April/May/June/July/August
	coneworms	Multiple (alternate with carbaryl)	May/June/July
	seed chalcids	Single	May
	western spruce budworm	Single	June
	Cydia spp.	Two	June
Esfenvalerate (Asana® XL)	cone beetles	Two	May/June
Carbaryl (Sevin®)	coneworms	Multiple (alternate with permethrin)	May/June/July
	western conifer seed bugs	Multiple (alternate with permethrin)	April/May/June/July/August
	western spruce budworm	Single	June
Dimethoate	coneworms	Two	May/June
Dormant oil (Omni Supreme Spray)	larch cone adelgids	Single	March
Insecticidal soap (M-Pede® by Gowen®)	larch cone adelgids	Single	May
Imidacloprid	woolly adelgids	Single	May/June/July
Vaportape™ II (Hercon®)	cone beetles	Placed in traps	March/April

The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

References to pesticides appear in this publication. Publication of these statements does not constitute endorsement or recommendation of them by the U. S. Department of Agriculture, nor does it imply that uses discussed have been registered. Use of most pesticides is regulated by state and federal laws. Applicable regulations must be obtained from the appropriate regulatory agency prior to their use.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish and other wildlife if they are not handled and applied properly. Use all pesticides selectively and carefully. Follow recommended practices given on the label for use and disposal of pesticides and pesticide containers.

Ponderosa Pine Cone Beetle, *Conophthorus ponderosae*

Hosts: western white pine, ponderosa pine, lodgepole pine, whitebark pine, and limber pine

Identification & Damage: Cone beetles are in the same subfamily as bark beetles (Scolytinae) and their life stages look similar. Adult cone beetles are 3-4 mm (about ⅜ inch) long, shiny black, and cylindrical. Larvae are white with light brown heads. Pupae are all white. Newly formed adults are brown and turn black when mature (Figure 1). Attacked cones often have distinct pitch tubes (Figure 2) or frass at their base and become stunted and turn brown (Figure 3). Most infested cones fall to the ground by late summer. Cone beetle adults may also infest and kill branch tips (Figure 4).

Life History & Habits: Adult beetles overwinter inside cones. In spring and early summer, beetles emerge to infest second year conelets. Female beetles initiate the attack and bore into the base of the cone, often forming a pitch tube. They girdle the cone axis, killing the cone, and then construct a straight gallery along the cone axis where they lay eggs in niches. Eggs hatch in 5-10 days. Larvae go through two instars (stage between molts) and feed indiscriminately on cone tissue and partially developed seeds, pulverizing cone contents to a fine brown powder. They turn into pupae in mid- to late-summer. Pupae transform into new adults before winter. Female beetles may feed on and kill cones without mating or producing any brood.

Impact: In some years, 90% cone loss has occurred in western white pine (Shea et al. 1983, Williamson et al. 1966).

Monitoring: Pheromone traps consist of yellow Japanese beetle trap tops with 250 ml clear plastic Nalgene™ cups (or similar) screwed in at the bottom. The plastic cups need tiny holes ($\leq 1/16$ inch) drilled in the bottom, or an inch-wide hole covered with a fine mesh screen for rain drainage (Figure 5). Traps are baited with 2 components—a pityol bubble cap and alpha-pinene in a plastic vial. Flexible wire or string is used to attach pheromone components to the yellow fin through the small hole on the trap top. A half strip of Vaportape™ II (Hercon®) or other insecticidal strip is placed in each cup to kill insects that are collected before they can escape. Traps should be placed in the upper third of tree crowns so that no parts of the trap top are blocked by foliage and away from any cones, in order to reduce attacks by beetles attracted to traps. Place two or three traps in each pine orchard block with a minimum distance of 15 meters (about 50 feet) between traps. Traps should be placed in spring when air temperatures consistently reach 60° F (usually by early April but can be earlier on warm sites). Beetles usually fly from April through June (Figure 6). Traps should be monitored weekly. Beetles caught determine spray timing.

Management: Infested cones should be removed or burned to destroy overwintering beetles before beetle flight in the spring. If insecticide treatments are warranted, spray when beetles are first caught in traps and again two weeks later (Shea et al. 1983). Synthetic pyrethroids registered for seed orchard use have been successful in reducing damage. The systemic insecticide, emamectin benzoate, injected into ponderosa pine boles, also reduced cone beetle damage (Cook et al. 2013). Stem injections of systemic insecticides could be considered for individual trees or families with high value seed.

Figure 1. Cone beetle life stages: mature adult beetle in gallery (upper left); larvae in cone (upper right); pupae in cone (lower left); new immature adult (lower right).

Figure 2. Orange pitch tubes at base of western white pine (left) and ponderosa pine (right) indicating infestation by cone beetles.

Figure 3. Stunted light brown western white pine cone (left) and ponderosa pine cone (right) indicating infestation by cone beetles.

Figure 4. Western white pine shoot infested by cone beetles (left); cone beetle in pith of shoot (right).

Figure 5. ***Left****: Trap used for cone beetles hung in upper 1/3 of crown. White arrow indicates lure placement;* ***Right****: bottom of cup showing 1" hole drilled and covered with fine mesh screen for rain drainage.*

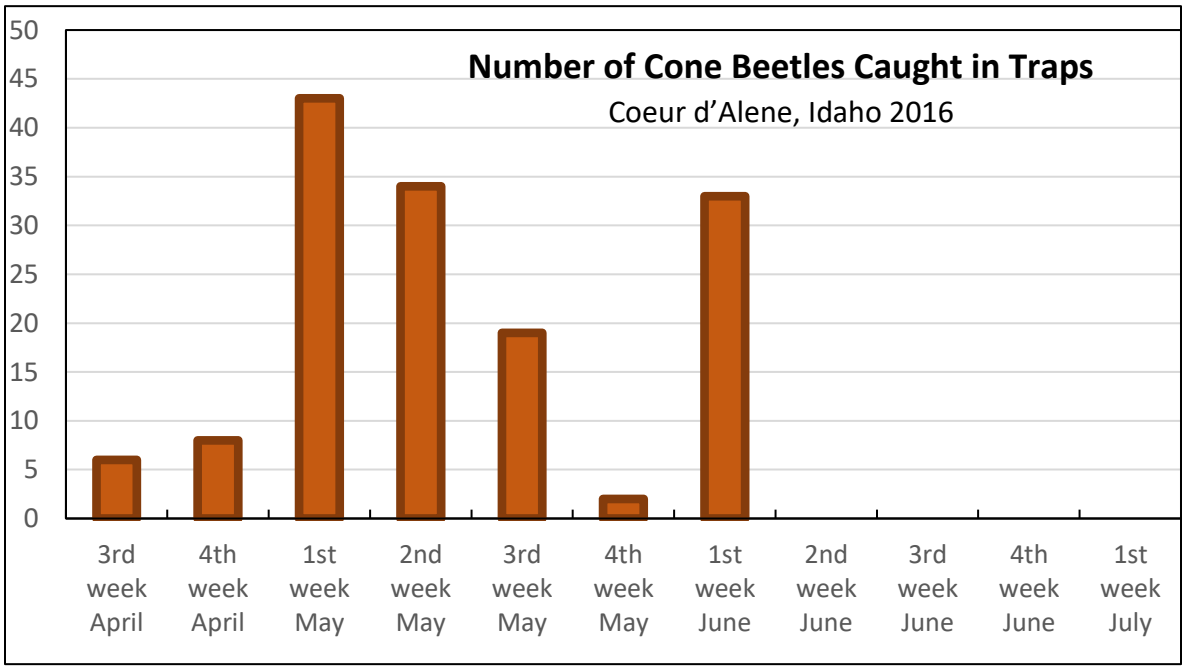

Figure 6. Number of cone beetles caught at the western white pine breeding orchard in Coeur d'Alene, Idaho (2260 feet elevation) in 2016. Traps were placed April 19 and monitored through July 6.

Western Conifer Seed Bug, *Leptoglossus occidentalis*

Hosts: western white pine, ponderosa pine, lodgepole pine, Douglas-fir, western larch, and other conifers

Identification & Damage: Adults are 15-18 mm (about ¾ inch) long and red-brown to dark gray in color, with a light zigzag line across the hemelytra, and flattened, expanded hind legs (Figure 7, left). Eggs are brown, barrel shaped and deposited in spring on needles of host trees (Figure 7, right). Early instar nymphs have reddish-orange abdomens and feed gregariously (Figure 8, left). Spring feeding by overwintered adults causes abortion of second-year developing pine conelets, damage to pine pollen catkins, and seed abortion in Douglas-fir (Connelly & Schowalter 1991, Schowalter & Sexton 1990). Both nymphs and adults feed on seeds in maturing cones throughout the summer, causing partially filled and empty seed (Strong 2015). Late season feeding (after cone harvest) by nymphs and adults causes abortion of first-year pine conelets (Bates et al. 2002).

Life History & Habits: Adults overwinter and there is one generation per year. Nymphs hatch from eggs starting in late June in British Columbia. There are five nymphal instars (Koerber 1962). Wing pads develop on later instars (Figure 8, right). Adults are very mobile and readily fly when disturbed. Nymphs scurry to the back of cones or hide in foliage when disturbed. Both adult and nymph seed bugs feed by inserting their sucking mouthparts through cone scales into developing seed (Figure 9). Seed contents are dissolved by bug saliva and sucked out of seeds. In autumn, adults often enter homes and other buildings to overwinter, becoming a nuisance to people. Seed bugs have infrared receptors on their abdomens and use infrared radiation emitted from cones, which are hotter than surrounding cool foliage, as foraging cues (Takacs 2008). Three egg parasitoids have been identified from British Columbia and California, and a tachinid fly parasite of adult *L. occidentalis* was found in Connecticut (Ridge-O'Connor 2001). The parasitic wasp, *Gryon pennsylvanicum*, showed potential for biological control of *L. occidentalis* and has been introduced in Italy, where *L. occidentalis* is an alien pest of stone pines (Maltese et al. 2012, Sabbatini Peverieri et al. 2012).

Impact: Heavy infestations can result in significantly reduced seed yield due to conelet abortion and seed loss. Seed bug feeding in western white pine cones early in the growing season caused 40% abortion of second-year conelets; feeding in both early (May) and late season (July and early August) reduced filled seed by 70- 80% (Connelly and Schowalter 1991). Feeding by female seed bugs caged on Douglas-fir cones for a two week period reduced full seeds by 70% (Bates et al. 2000).

Monitoring: Monitoring is accomplished by timed visual inspections on dry days when air temperature is between 60-90°F. Numbers of seed bugs observed are counted in a 30 minute walk through an orchard inspecting developing cones and pollen catkins. If any seed bugs are observed, treatment should be considered. Monitoring should occur every 2 weeks throughout the growing season. There are no known pheromones. Experimentation with black sticky cards placed near cones for monitoring was not successful because seedbug adults were able to walk off the traps (Figure 10). Because seed bugs are attracted to hot cones, development of heated traps for monitoring is currently being investigated. Damage can be detected in radiographs of extracted seed (Figure 11).

Management: Seeds have been protected from seed bug feeding by installing mesh bags over second year pine cones (Strong 2015). Seed bugs are very susceptible to insecticides. Damage can be reduced in seed orchards by using contact insecticides when seed bugs are observed. Multiple treatments may be necessary.

Figure 7. ***Left****: Western conifer seedbug adult (arrows point to characteristic zigzag pattern on back and expanded hind legs);* ***Right****: barrel-shaped eggs (hatched) on pine needle.*

Figure 8. ***Left****: Newly hatched western conifer seedbug nymphs;* ***Right****: Later instar nymph with developing wing pads.*

Figure 9. Western conifer seedbug adult (left) and nymph (right) feeding on western white pine cones. Arrows point to the stylet (inner part of their mouthparts) they insert into cones.

*Figure 10. **Left**: Black sticky card placed near western white pine cones to catch seed bugs; **Right**: seed bug slowly walking off sticky trap. These traps were not successful for monitoring seed bugs.*

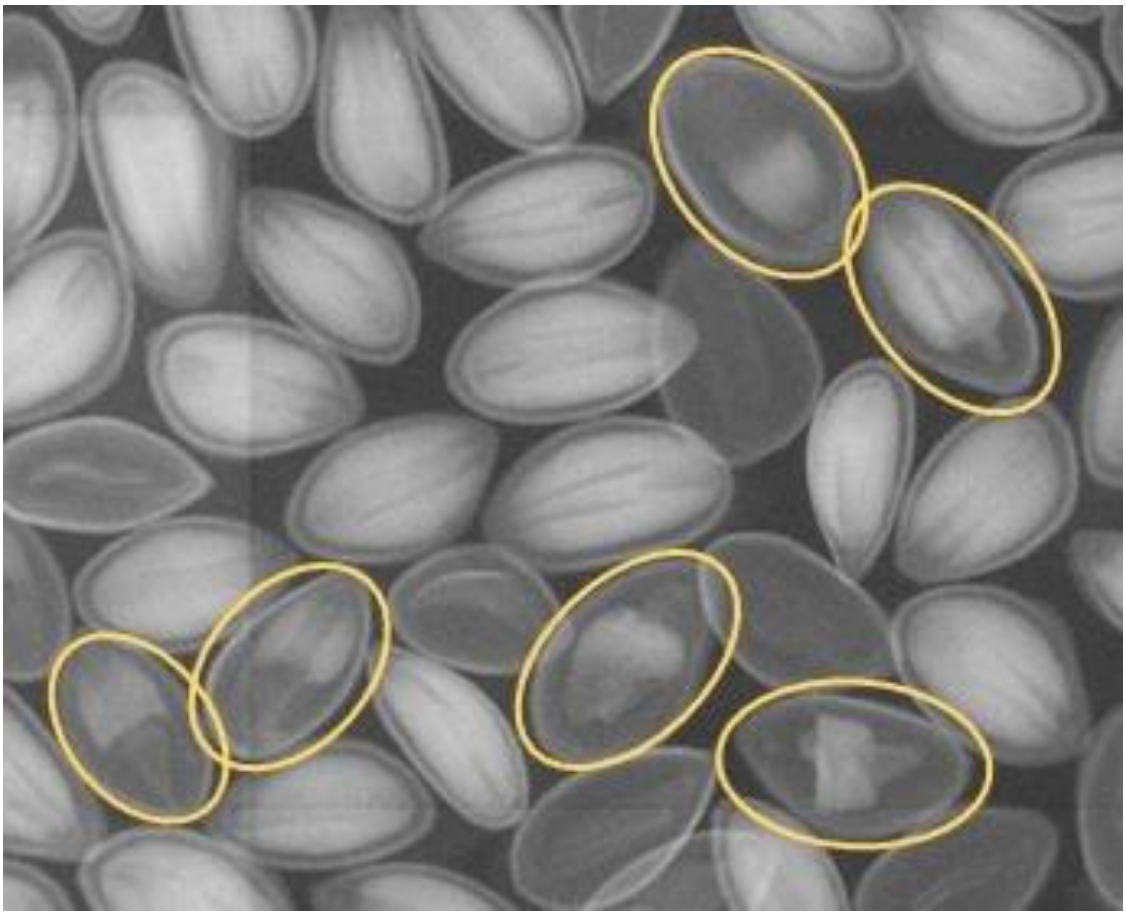

Figure 11. Radiograph of ponderosa pine seed showing white, normal filled seed, and partially empty seed (circled) caused by seed bug feeding.

Coneworms, *Dioryctria* spp.

Hosts: pines, Douglas-fir, true firs, spruce, western larch

Identification & Damage: Coneworm damage is easily recognized by coarse webbed frass on the outside of cones (Figure 12). Larvae are amber or purplish in color with light to dark brown head capsules (Figure 13). Pupae are brown or dark amber in color (Figure 14, left). Adults have narrow grey forewings with zigzag patterns of lighter and darker grey (Figure 14, right); hindwings are lighter in color with no markings. Their wingspan is 25-28 mm (about one inch). The most common species in R1 is *Dioryctria abietivorella* but there may be other species. Some *Dioryctria* species feed in graft unions or on white pine blister rust cankers and damage can be recognized by their coarse webbed frass.

Life History & Habits: Life history is variable. Larvae develop from June through September in developing cones. Some larvae pupate in cocoons on the ground during July, August, and September and adults emerge in the fall to lay eggs, which overwinter. Other larvae overwinter as prepupae in hibernacula inside cones or in the duff beneath trees and adults emerge in May and June. Eggs are laid on twigs and cone bracts. Larvae feed indiscriminately on seeds and cone tissue throughout the summer. Larvae are very mobile and often feed on multiple cones. They can continue to feed on cones post-harvest while cones are stored.

Impact: Coneworms have reduced seed yield by 44% in a western white pine seed orchard (Haverty et al. 1986) and have been very damaging in Douglas-fir cones at Bigfork Tree Improvement Area (TIA), Montana.

Monitoring: Commercial pheromones are available and used in sticky traps for monitoring and timing insecticide treatments (Willhite et al. 2011) (Figure 15). Traps should be hung in the upper third of tree crowns and monitored weekly. In 2017 at Bigfork TIA, first moths were caught May 30 and peak flight occurred July 17 in Douglas-fir and western larch blocks (Figure 16).

Management: Insecticides are effective in managing coneworm populations in seed orchards. Two applications of fenvalerate, a synthetic pyrethroid, applied in May and again in June, significantly increased seed yield in western white pine (Haverty et al. 1986). Synthetic pyrethroid insecticide applications used at Bigfork TIA seven days after moths were first caught and again two or three weeks later was successful in reducing damage in Douglas-fir. Emamectin benzoate injected into ponderosa pine boles significantly reduced damage from coneworms (*Dioryctria* sp.) (Cook et al. 2013).

Figure 12. Webbed frass from coneworm feeding on cones of western larch (left), western white pine (center), and Douglas-fir (right).

Figure 13. Dioryctria larvae in cones with body color ranging from amber to purplish and heads light brown to very dark.

Figure 14. ***Left****: coneworm pupa;* ***Right****: coneworm adult moth.*

Figure 15. ***Left****: sticky trap for monitoring coneworm moths;* ***Right****: open trap showing moths caught.*

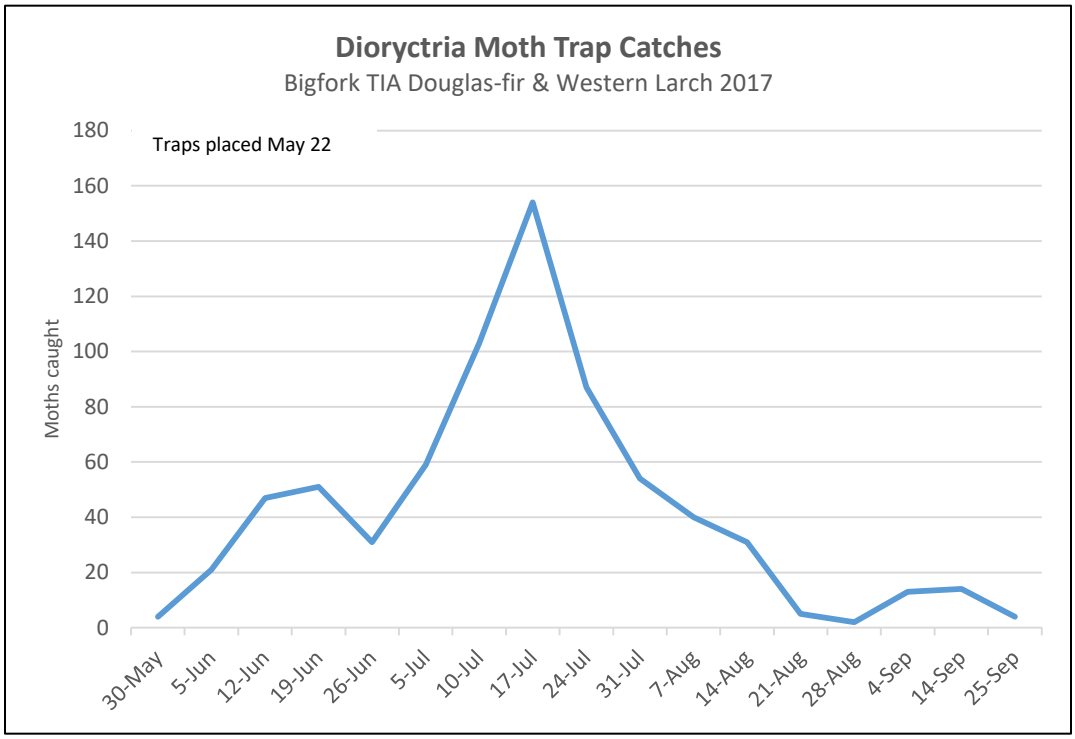

Figure 16. Number of Dioryctria moths caught in pheromone traps at Bigfork TIA, Montana (3050 feet elevation) in Douglas-fir and western larch blocks in 2017.

Seedworms, *Cydia piperana* complex

Hosts: ponderosa pine

Identification & Damage: Two species of seedworms, *Cydia miscitata* and *C. piperana*, have been reported to occur in Idaho and Montana (Dale & Schenk 1978, 1979; Rust 1937). More recently, these species were grouped with *C. injectiva* (Heinrich) in the *Cydia piperana* complex because of difficulty in distinguishing them on the basis of existing descriptions (Stevens et al. 1985, Sartwell et al. 1985). Infested cones appear normal externally. Larvae are white with brown heads and mature larvae may be found in the pith of bisected cones in late July and August (Figure 17). Damaged seeds are full of insect frass (Figure 18). Moths are small, about 6-7 mm (¼ inch) long, dark grey with lighter colored bands across the forewings or a mottled brown and grey pattern (Figure 19).

Life History & Habits: Moths fly from May-July but most are reported to emerge in May and early June. Eggs are laid in clusters in crevices between cone scales, on the tips of scales, or in the papery scales of the cone peduncle. Larvae enter the cone between cone scales. A small globule of pitch may exude from the tiny larval entry hole, but there are no other external signs of infestation. Newly hatched first instar larvae feed in developing seed and remain in the first seed encountered through development to third instar. Movement to subsequent seed occurs in July. They are reported to have five larval instars. In late July or early August, larvae move to the cone axis where they make extensive tunnels and overwinter. There can be several larvae in one cone. Pupae were present in mid-March to mid-May (Dale & Schenk 1979, Hedlin 1967).

Not all moths emerge in the spring after cone damage occurs. Some (18-80%) remain in diapause and emerge two years after cones are attacked (Dale & Schenk 1979, Hedlin 1967, Rust 1937).

Impact: Seedworms have reduced seed yield by 25-50% (Dale & Schenk 1978, Hedlin 1967, Rust 1937). Populations have been high at Plains TIA, Montana from 2015-2017.

Monitoring: A pheromone (70:30 blend of (E)-9- and (Z)-9-dodecenyl acetate) that was developed for trapping shoot moths (*Rhyacionia* and *Eucopina*), also catches *Cydia* moths. It is available by special order (ChemTica International) and can be used in sticky traps for monitoring and timing insecticide treatments (Kegley & Sturdevant 2018). Traps should be monitored weekly. *Eucopina* and *Cydia* moths were caught at Plains, Montana but are easily distinguished (Figure 20). *Cydia* moths were caught in June and July and *Eucopina* in April and May (Figure 21).

Frass filled seed can be detected in radiographs (Figure 18, right).

Management: Since seedworms overwinter as larvae in cones, removing or burning all cones that are not harvested would reduce on-site populations. However, that would not prevent immigration of moths from surrounding ponderosa pine stands. An imidachloprid soil drench applied in May did not translocate to ponderosa pine foliage or cones in time to affect seedworm populations that year (unpublished data).

Using pheromone traps to time topical contact insecticide applications, similar to a regime used for *Dioryctria* spp., would be worth investigating for *Cydia*.

Figure 17. Cydia larva in the pith of an infested cone.

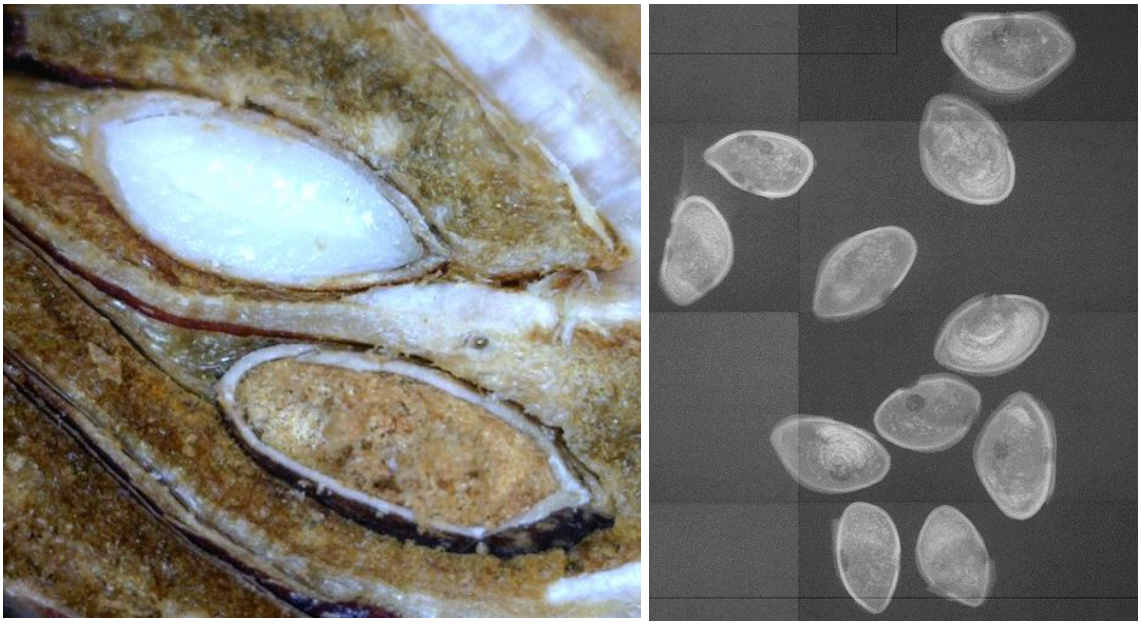

*Figure 18. **Left**: frass filled seed (bottom) compared to a white normal seed (top); **Right**: frass filled seed in radiograph.*

Figure 19. Cydia moths reared from infested cones showing a variety of grey and brown wing patterns.

*Figure 20. Moths caught in sticky traps, **left**: Cydia sp. shown next to rubber septa lure and **right**: Eucopina sonomana.*

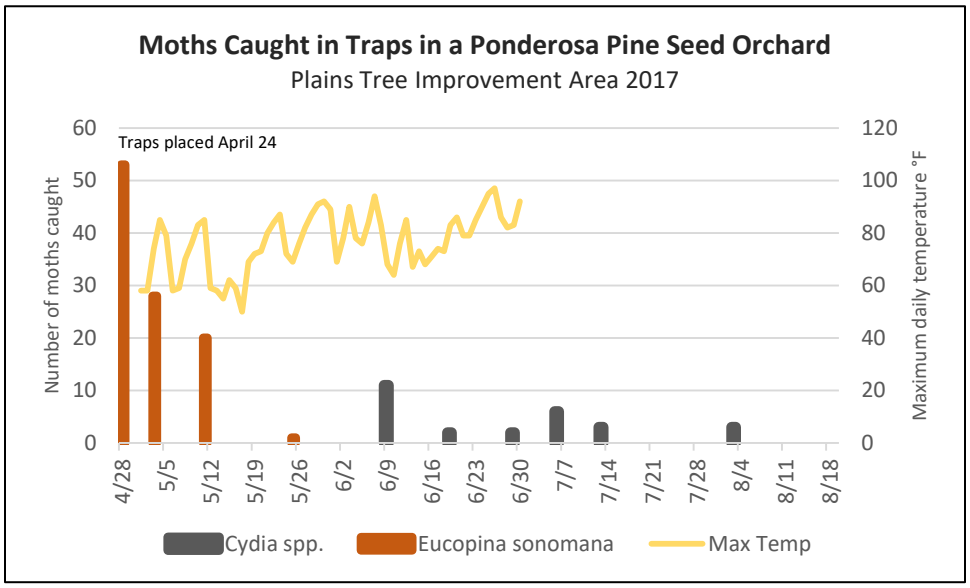

Figure 21. Number of Cydia spp. and Eucopina sonomana caught with daily maximum temperature by date at Plains TIA, Montana (2465 feet elevation) (Kegley & Sturdevant 2018).

Western Spruce Budworm, *Choristonera freemani* (formerly *C. occidentalis*)

Hosts: Douglas-fir, western larch, grand fir, spruce

Identification & Damage: Western spruce budworm mainly eats the foliage of its hosts but can also damage flowers and developing cones during outbreaks. Webbing, frass, and larvae can be found in damaged cones (Figure 22). Larvae are greenish brown with brown heads and rows of lighter colored dots on their backs (Figure 23). Adults have wing spans of about 20-30 mm (about ¾ - 1.2 inches) and wings are typically orange, brown, and gray in color with a variety of patterns (Figure 24).

Life History & Habits: Western spruce budworm overwinters as young larvae in webbed hibernacula on host tree bark. They become active early in the spring and feed on buds and male and female flowers. Later they feed on expanding foliage and developing cones. Pupation occurs in mid-summer and moths fly in mid- to late summer. Eggs are laid on host tree needles. Newly hatched larvae do not feed until spring.

Impact: Damage to Douglas-fir cones in western Montana averaged 36-62% with a high of 98% during two consecutive years of a budworm outbreak (Dewey 1970). Severe damage also occurred in western larch cones (Fellin & Shearer 1968). Budworm damage has been observed on Douglas-fir at Bigfork TIA.

Monitoring: Pheromones are available to monitor western spruce budworm moths (Niwa & Overhulser 2015), but have not yet been used in seed orchards. Budworm larvae and damage can be found by visual examination of foliage and cones, especially during outbreaks.

Management: Douglas-fir cones have been protected from western spruce budworm damage by using Acecap® implants inserted in trees in early April, when cone buds were swollen but vegetative buds still tight (Reardon et al. 1985) (Figure 25). Contact insecticides can also be used and should be sprayed early, when seed cones elongate to about one inch but before pollination is complete (Stipe 1984).

Figure 22. Developing Douglas-fir cone damaged by western spruce budworm. Note webbing and frass on cone. Larva indicated by arrow.

Figure 23. Budworm larvae with characteristic lines of white dots on their backs in developing Douglas-fir cones.

Figure 24. Western spruce budworm moths with different wing patterns.

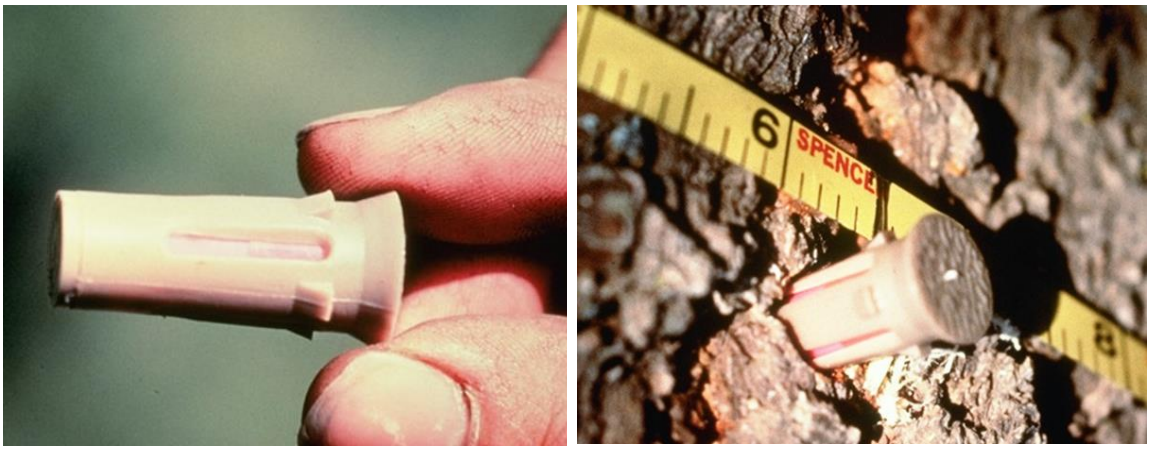

Figure 25. Acecap® implants are inserted into the bole of Douglas-fir to deliver systemic insecticides that reach cones in the crown and reduce damage from western spruce budworm.

Douglas-fir Cone Moth, *Barbara colfaxiana*

Hosts: Douglas-fir

Identification & Damage: Some cones show no external signs of infestation while others may be misshapen with frass on the surface. *Barbara* frass is finer than *Dioryctria* frass. Early instar larvae are white with a black head and older larvae are pinkish to yellowish with brown heads (Figure 26). Multiple larvae may be in a cone. Moths have a wingspan of 15-20 mm (about ½ - ¾ inch) and forewings are banded with grey, silver, and brown (Figure 27).

Life History & Habits: Moths emerge when Douglas-fir flowers are open for pollination, typically April to early May. They fly during evenings and are particularly active after dusk during warm weather. Eggs are laid individually on cone bracts. Larvae feed first on scale tissue, and then later on seeds. It pupates in a tough, pitchy cocoon near the cone axis in mid- to late July and overwinters in the cone. Some may remain in cones in extended diapause for more than one year (Hedlin et al. 1981, Hedlin 1974).

Impact: Douglas-fir cone moths were found in many locations in Montana (Dewey 1972) and have been considered a major pest of Douglas-fir. One larvae can destroy up to 60% of the seeds in a cone (Hedlin et al. 1981). Douglas-fir cone moth has not yet been a problem in R1 seed orchards.

Monitoring: Douglas-fir cone moth is reported to be attracted to the Douglas-fir cone gall midge (*Contarinia oregonensis*) pheromone (Forest Pest Insects in North America), which is commercially available, and can be monitored with sticky traps (Figure 28).

Management: A foliar spray of a systemic insecticide, applied after pollination is complete and the majority of cones are horizontal, has provided control (FGC Pest Leaflet No. 8).

Figure 26. Larvae of Douglas-fir cone moth. Photo by D. Manastyrski, Bugwood.org

Figure 27. Douglas-fir cone moth adult with grey, brown, and silver colored wing markings. *Photo by Julie Brooks, Bugwood.org.*

Figure 28. Douglas-fir cone moth caught in sticky trap with gall midge pheromone. *Photo by Ward Strong, BC Ministry of Forests, Bugwood.org*

Seed Chalcids, *Megastigmas* spp.

Hosts: Douglas-fir, pines, spruce, true firs

Identification & Damage: There are no external signs of seed chalcid damage on cones. Individual larvae develop within one seed. Larvae inside seed can be detected by radiographs or by seed dissection (Figure 29). Adults are small wasps, 3-4 mm (about ⅛ - $^{3}/_{16}$ inch) long, with a dark spot on each forewing (Figure 30). Round exit holes made by mature wasps are evidence that seeds were infested (Figure 31).

Life History & Habits: Adults emerge in spring after pollination is complete. For Douglas-fir seed chalcid, emergence occurs mid-April to late May (Hedlin et al. 1981). Females use their ovipositors to bore through cone scales and deposit eggs near developing seed. Individual females can lay up to 150 eggs. Larvae hatch from eggs within a few days and enter seeds. A single larva develops in an individual seed. Infested seeds develop a normal seed coat. Larvae mature in 6-8 weeks and overwinter inside seeds that are either released from cones and fall to the ground or are retained inside cones. Pupation occurs in the spring. Part of the population remains in diapause for more than one year (FGC Pest Leaflet No. 7, Hedlin et al. 1981).

Impact: Seed losses of 47% have been reported from Douglas-fir seed chalcid (Schowalter et al. 1985). Douglas-fir seed chalcid utilizes both unfertilized and fertilized seeds (Niwa & Overhulser 1992), therefore, seed loss estimates that assumed all infested seed were fertilized may have exaggerated impacts (Rappaport et al. 1993). Seed chalcid larvae are often observed in seed radiographs from other conifer species, but the Douglas-fir seed chalcid appears to be the most important in R1.

Monitoring: Seed chalcid wasps can be monitored by using yellow sticky panel traps (Figure 32). Place 10-30 traps per seed orchard block or one trap per acre (Sandquist & Sprengel 1994). Catches of one female per trap predict 20% seed loss in the current year (Niwa 1995). However, many other small insects are caught on the sticky traps, making it difficult and time consuming to identify and count seed chalcids.

Management: Removing all Douglas-fir cones before cones open and release seed will reduce resident populations. Cone development can be used to time insecticide treatments for seed chalcids in Douglas-fir. Systemic insecticide application should occur when cones are horizontal to pendent. Contact insecticide treatment should occur one or two weeks after cones turn pendent (Overhulser & Sandquist 1985). Cones turn pendent about mid-May at Bigfork TIA, Montana (3050 feet elevation).

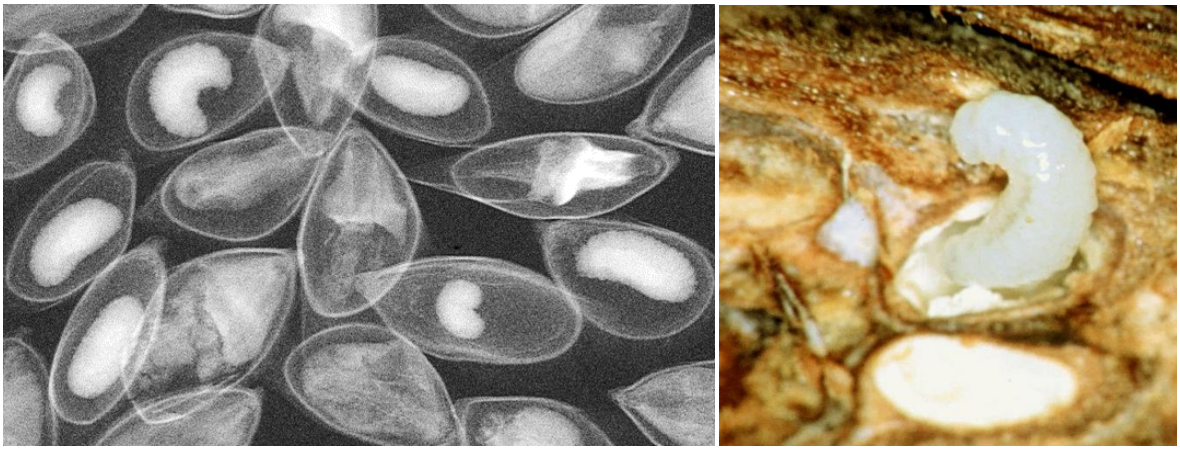

Figure 29. ***Left****: Radiograph of Douglas-fir seed with seed chalcid larvae;* ***Right****: seed chalcid larvae in a seed inside cone. Photo on right from Region 6 Forest Health Protection*

Figure 30. Adult female seed chalcids. Left: photo by Canada, webforestry.ubc.ca; right: photo by F.P.Keen, 1916, USDA Forest Service, R6 FHP, Bureau of Entomology Collection, LaGrande, OR.

Figure 31. Round exit holes in Douglas-fir made by adult chalcid wasps.

Figure 32. Yellow sticky panel trap for monitoring seed chalcids. Traps catch many different insects in addition to seed chalcids.

Douglas-fir Cone Gall Midge, *Contarinia oregonensis*

Hosts: Douglas-fir

Identification & Damage: Larval feeding inhibits seed development and causes distinctive galls (Figure 33) that fuse seeds to the scales and prevent extraction. Infested cones may have external browning of cone scales. First and second instar larvae are colorless or white and may be seen in cone scales (Figure 34, right). Third instar larvae are orange (FGC pest leaflet No. 2) and assume a characteristic U-shape in the galls. Infested cone scales turn reddish-brown at the end of summer. Male Douglas-fir cone midges can be differentiated from other midge species by their orange abdomens, long antennae with 24 round "beads", wings with only 3 dark veins, upturned male genitalia, and legs much longer than their body (Figure 34, left). They are 2.3-2.8 mm (about 1/16 - 1/8 inch) long (Willhite et al. 2004).

Life History & Habits: The adult midge emerges from a cocoon in the litter or soil in early spring when Douglas-fir flowers are open for pollination. Eggs are laid at the base of a newly opened flower. Larvae hatch in May through early June, chew into developing cones and form a gall (swollen area) near the ovules. Larvae complete their feeding by the time cones mature. They leave the cone in autumn, drop to the ground, and spin cocoons in the litter or soil and overwinter as pre-pupae or pupae (Hedlin 1961). A portion of the population can remain in diapause for more than one year (Hedlin et al. 1981).

Impact: Douglas-fir cone gall midge is reported to be the most destructive pest of Douglas-fir cone crops in coastal British Columbia and is also an important pest of interior Douglas-fir (FGC Pest Leaflet No. 2). It has destroyed 11-80% (mean 45%) of the Douglas-fir seed crop in 17 seed orchards in Washington, Oregon, and California (Schowalter et al. 1985). Douglas-fir cone gall midge has not yet been a problem in R1 seed orchards.

Monitoring: Pheromone traps are available for monitoring Douglas-fir cone gall midge. Ten baited sticky wing traps per orchard block are recommended and should be deployed one week before reproductive bud break (late March to early April). Traps should be placed along a transect through the center of a Douglas-fir block. They can be placed on any branch within reach and should be monitored daily if used for insecticide application timing. A 10x or higher magnification hand lens is necessary to identify cone gall midges (Willhite et al. 2004; a guide is available at Using Douglas-fir cone gall midge pheromone traps).

Management: Damage can be reduced by properly timed applications of synthetic pyrethroid insecticides or a systemic insecticide (Sandquist et al. 1993, FGC Pest Leaflet No. 2). Insecticide applications should occur 3-5 days after detection of the first cone gall midge in pheromone traps.

Figure 33. Douglas-fir cones: one on left with several normal filled seed; three on right are totally damaged from cone gall midge. Photo from Region 6 Forest Health Protection.

*Figure 34. **Left**: adult cone gall midge. Photo by Richard Worth, Oregon Department of Agriculture; **Right**: cone midge larvae in scales. Photo from Region 6 Forest Health Protection.*

Cone Adelgids, *Adelges lariciatus, A.laricis, Pineus* spp.

Hosts: Western larch, spruce, pines, Douglas-fir

Identification & Damage: Adelgids are tiny, soft bodied, sucking insects that feed on cones and other tree parts by inserting their long mouthparts into plant tissue. Adults develop a woolly covering that makes cones and other tree parts look white (Figure 35).

Life History & Habits: Adelgids have complex life cycles that involve different life forms alternating between two host species. The larch cone adelgid alternates between spruce and larch. Nymphs overwinter on and around dormant larch buds (Figure 36, top). In early spring, they enlarge, mature into wingless females, lay eggs and produce a white, waxy "wool" covering. Eggs are often laid at the base of developing cones on larch spur shoots and can be very abundant (Figure 36, center & bottom). Eggs hatch in May or June and nymphs feed on developing cones. A second generation is usually produced on cones. Mature winged females fly to spruce in mid-summer. On spruce, females produce a generation of males and females. Mating occurs and eggs are laid that develop into female nymphs. These nymphs overwinter on spruce twigs. In spring they mature and migrate to expanding buds. Their feeding cause galls to form on spruce tips and nymphs develop in chambers within the galls. When nymphs turn into adults, galls open and winged females emerge and fly to larch (FGC Pest Leaflet No. 9).

Impact: Larch cone adelgid can affect seed extraction because of pitch and honeydew on cones from adelgid feeding. Little is known about their direct impact on seeds.

Monitoring: Monitor larch cone adelgid nymphs on dormant larch buds in early March with a 10x hand lens or a head-mounted binocular magnifier (Figure 37).

Management: If many adelgids are found on larch buds, apply dormant oil spray before bud break in mid- to late March. Good coverage on buds is essential. Alternatively, spray trees with 2% insecticidal soap, thoroughly to the point of runoff, when nymphs are actively migrating to foliage or cones later in spring. Spraying must occur before adelgids develop a protective woolly covering. Adelgid populations increase markedly after excessive nitrogen fertilization. Balanced fertilizers should be used in seed orchards (FGC Pest Leaflet No. 9).

Figure 37. Binocular magnifier that can be used for monitoring adelgid nymphs. Photo by Marie McLaughlin.

Figure 35. Adelgids with woolly covering on Douglas-fir cone (top left), whitebark pine cone (top right) and western larch foliage (bottom).

Figure 36. ***Top****: overwintering larch adelgid nymphs on larch bud. Photo by W. Strong, British Columbia, Canada;* ***Center****: adult adelgid with eggs at base of developing cone;* ***Bottom****: numerous eggs on larch spur shoots.*

Cone maggot, *Strobilomyia laricis*

Hosts: western larch, tamarack (eastern larch)

Identification & Damage: Adults look like a typical housefly (Figure 37, left) and larvae are small, whitish maggots (Figure 37, center). Eggs are ovoid in shape, about one mm long, and beige with a patterned surface (McClure et al. 1996). There are no external signs of damage on cones. Larvae destroy developing seeds as they feed spirally along a cone axis (Amirault & Brown 1986).

Life History & Habits: Information on the biology of cone maggots in the West is scarce. On tamarack in New Brunswick, *Strobilomyia* (= *Lasiomma*, = *Hylema) laricis* eggs are laid one per cone in the curled bud scales at the base of the cone from mid- to late May (Figure 37, right). Larvae become established in cones by early June. By mid-July, larvae leave the cones and drop to the ground to pupate and overwinter (McClure et al. 1996; Amirault & Brown 1986).

Impact: Cone maggots were widespread throughout 14 sites in Montana, Idaho, Washington, and Oregon and considered a major pest of western larch cones (Jenkins & Shearer 1988). They have not yet been a problem in R1 western larch seed orchards.

Monitoring: Visual inspection of cones for eggs or of bisected cones for larvae.

Management: Two applications of dimethoate (applied at rates of 30 or 40 g active ingredient per 10 L of water with a mist blower in early May and June) significantly reduced damage compared to controls on tamarack in New Brunswick (Amirault & Brown 1986).

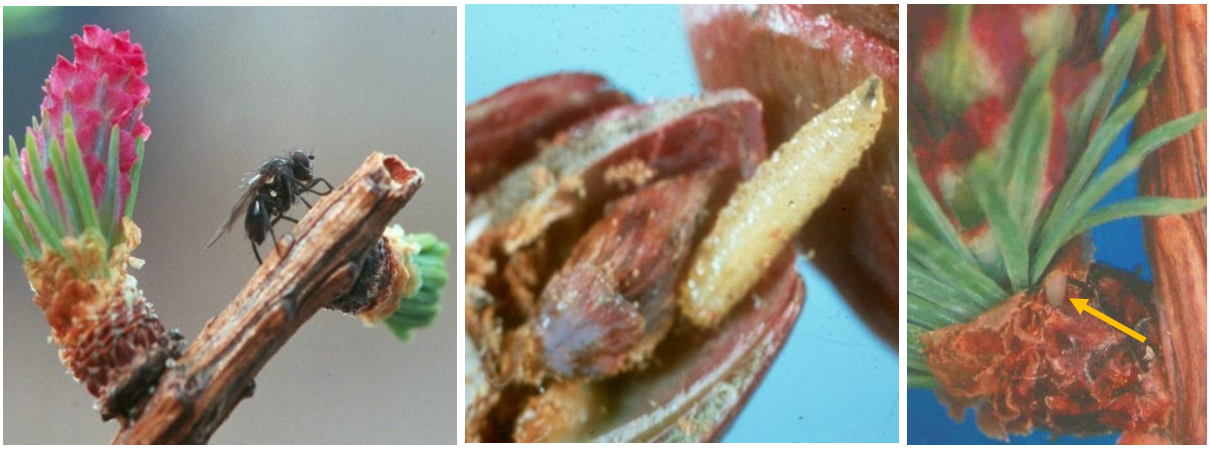

Figure 37. ***Left****: Adult cone maggot;* ***Center****: cone maggot larva;* ***Right****: arrow points to cone maggot egg on bud scales at base of developing cone. Photos by E. Brokerhoff, T. Arcand, and J. Turgeon, respectively, Canadian Forest Service.*

Resin/Cone Scale Midges, *Resseliella* spp.

Hosts: Pines, Douglas-fir, western larch

Identification & Damage: Larvae are small and bright orange (Figure 38). External signs of infestation are brown cone scales on western larch (Figure 39).

Life History & Habits: Larvae emerge from cones and overwinter in the duff. Adults emerge in spring.

Impact: Reported to be of minor importance on western larch and grand fir. These midges caused an average of 20% seed loss in European larch in Poland (Skrzypczynska 1985).

Monitoring: Visual inspection of bisected cones for larvae. Large numbers of larvae were captured on drop trays placed under tamarack trees in late July (Amirault & Brown 1986) and might be useful for monitoring.

Management: No known management options.

Figure 38. Orange resin midge larvae emerged from ponderosa pine cone (left) and inside a western larch cone (right).

Figure 39. Brown cone scales caused by resin midges.

Xyelid Sawfies, *Xyela* spp.

Hosts: Pine pollen structures ("pollen catkins")

Identification & damage: Xyelid larvae are most often seen when they emerge from mature pollen catkins during pollen extraction (Figure 40, top left). Larvae are white with light brown heads (Figure 40, right). Larval feeding may cause sunken areas or browning on immature pollen catkins (Figure 40, bottom left).

Life history & habits: Adults emerge early in the spring and lay eggs on pollen catkin buds as they start to elongate. Larvae feed on pollen and develop in two to four weeks. Larvae drop to the soil to pupate when pollen catkins mature and shed pollen. They may remain in the soil for more than one year (Hedlin et al. 1981).

Impact: Larvae may reduce or contaminate available pollen. This could be a problem on particular clones for artificial breeding work. These sawflies are not considered a problem in the general forest. They are sometimes a public nuisance when larvae drop from trees to pupate in the soil and land on picnic tables or other outdoor items underneath pine trees.

Monitoring: Visual inspection of pollen cones for damage or drying trays for larvae.

Management: No known management options.

Figure 40. ***Top left****: Xyela sawfly larvae emerged from pine pollen catkins during pollen extraction;* ***Right****: close-up of larvae. Photo by Whitney Cranshaw, Colorado State Univ., Bugwood.org;* ***Bottom left****: damage to pine catkins. Photo by North Carolina Forest Service, Bugwood.org.*

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Appendix

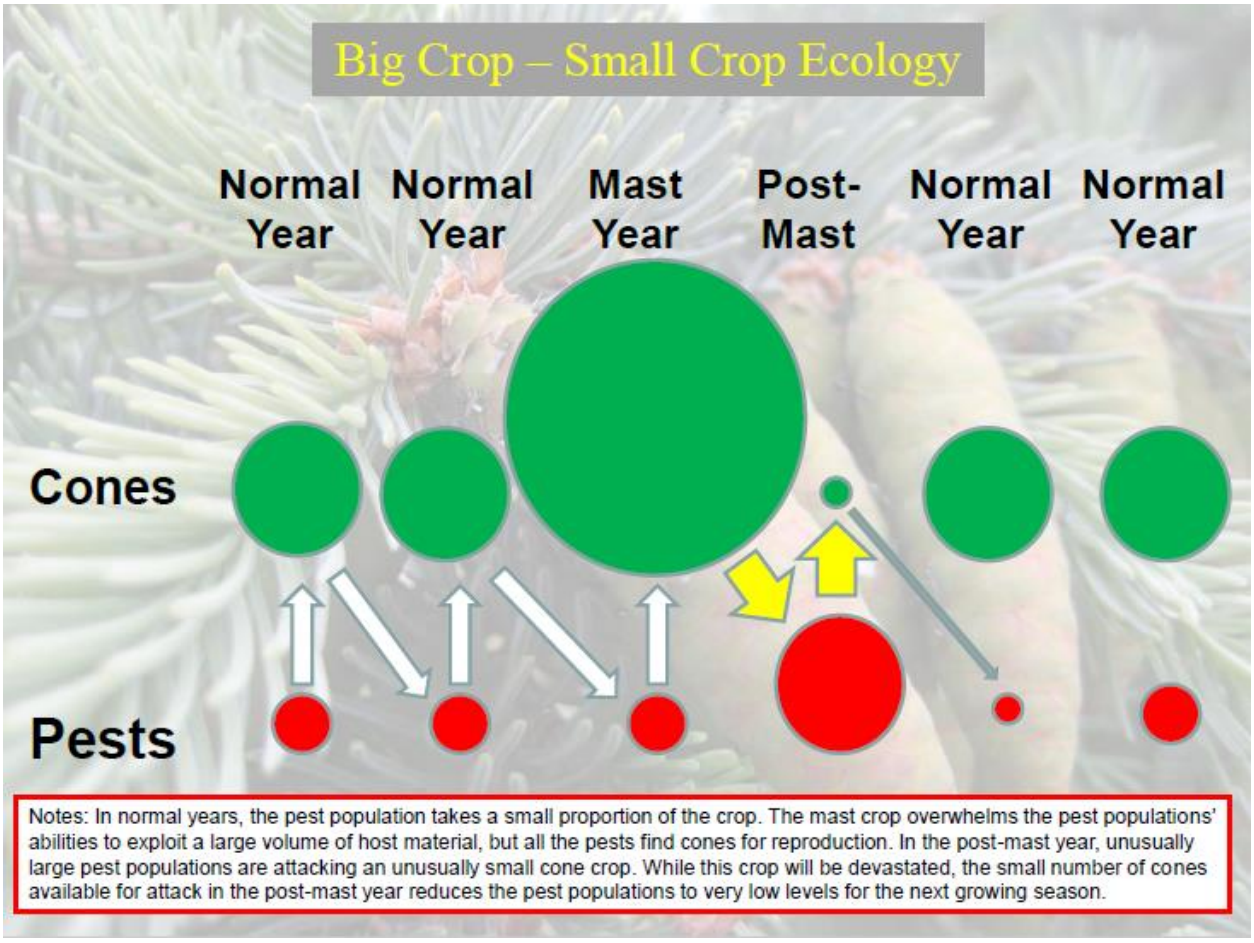
Big Crop – Small Crop Ecology
Normal Year
Normal Year
Mast Year
Post-Mast
Normal Year
Normal Year
Cones
Pests
Notes: In normal years, the pest population takes a small proportion of the crop. The mast crop overwhelms the pest populations' abilities to exploit a large volume of host material, but all the pests find cones for reproduction. In the post-mast year, unusually large pest populations are attacking an unusually small cone crop. While this crop will be devastated, the small number of cones available for attack in the post-mast year reduces the pest populations to very low levels for the next growing season.

Figure 41. An illustration of cone crop fluctuations and insect pest population response to those fluctuations. Information provided in a presentation by Jim Corrigan, Seed Orchard Pest Biologist, British Columbia Ministry of Forests.